SEMIARID PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40, Technical Paper No. 49* and *NOAA Atlas 2*

Eighteenth Progress Report
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Hydrometeorological Design Studies Center
Hydrology Laboratory

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DISCLAIMER

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TABLE OF CONTENTS

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1. Introduction.

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency analysis for the Semiarid Southwestern United States. Current precipitation frequency studies for the Semiarid region are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964) and *NOAA Atlas 2* "Precipitation-Frequency Atlas of the Western United States." The new study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual and seasonal precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the Semiarid study area and use accepted statistical methods. In particular, the Semiarid Study is the pilot study in which decisions regarding the methods and format are being made that will affect subsequent studies. The study results will be published as Volumes of *NOAA Atlas 14*. They will also be made available on the internet using web pages with the additional ability to download digital files.

The Semiarid study area includes 4 states completely, Arizona, Nevada, New Mexico, and Utah, and southeastern California. Additional data from 7 bordering states and Mexico (Figure 1) were included for continuity. The core and border states, as well as regions used in the analysis, are shown in Figure 1. Warm and Cool season months for each region are also shown in Figure 1.
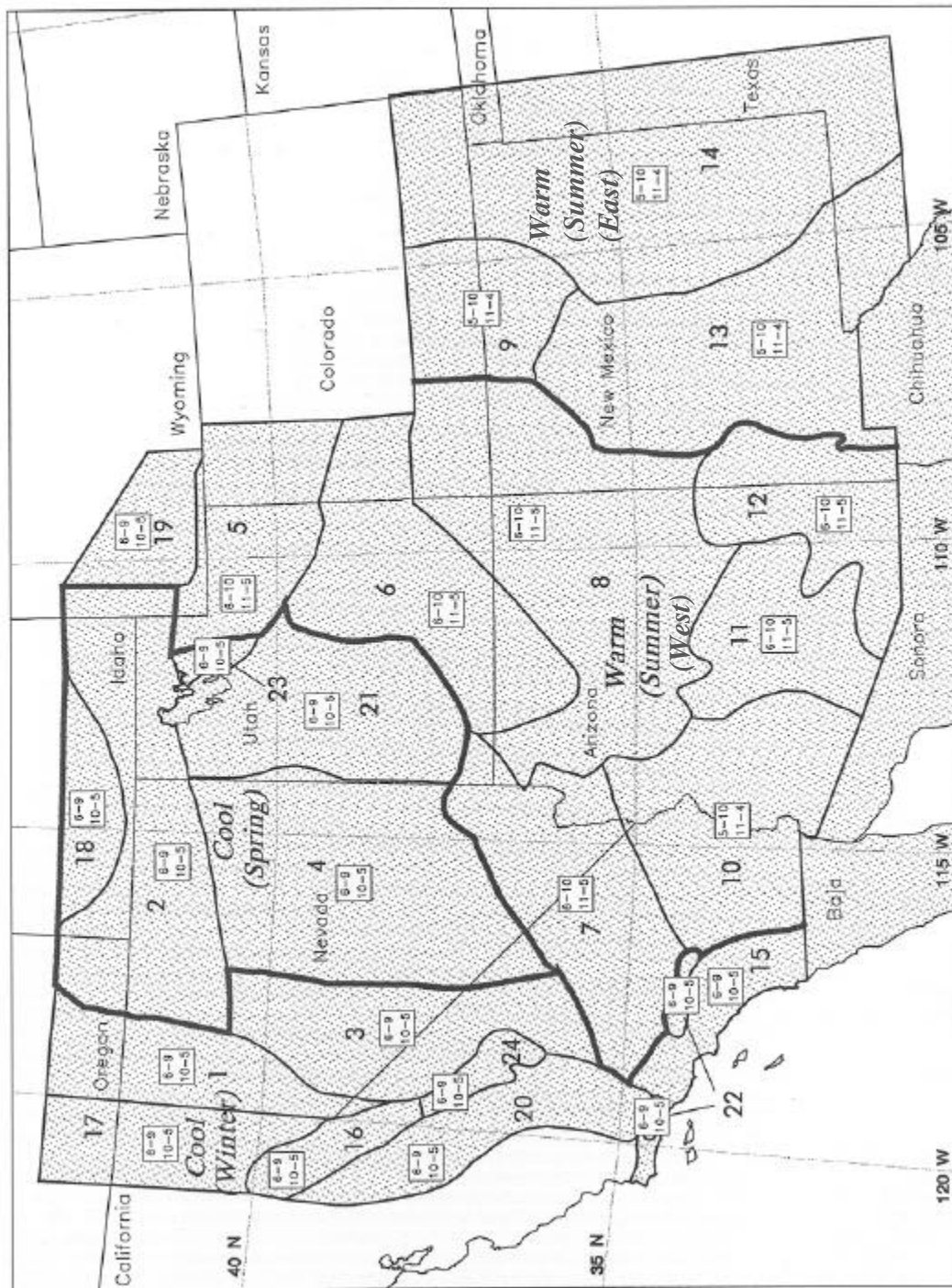
Figure 1. Semiarid Precipitation Frequency study area and region boundaries.

2. Highlights.

NCDC has recently provided us with their TD3206 daily dataset, which is primarily data before 1949. We are adding this data to the dataset and will proceed quickly with the quality control. Also, the Riverside Flood Control District provided additional n-minute data. These data have been formatted and are being quality controlled and evaluated for use in precipitation frequency calculations. Additional information is provided in Section 4.1, Update of Data Collection and Quality Control.

L-moment and discordancy checks have been completed for daily and hourly data through December 2000. Additional information is provided in Section 4.2, Update of L-moment Analysis.

Trend Analysis software has been refined. It will be a simple task to run the software once the daily dataset is complete. The Trend Analysis tests longer records for linear trends and shifts in annual maximums. As part of this task, the procedure for extracting annual maximums from the Semiarid data has been revised. Additional information is provided in Section 4.3, Update of Data Trend Analysis.

Work on the Internet-based Precipitation Frequency Data Server has continued for the Semiarid Southwestern United States Precipitation Frequency Project. In particular, areal calculation of precipitation frequencies has been modified to allow user-entered longitude/latitude points to establish the size of the area. An improved web page framework has also been developed. The Precipitation Frequency Data Server will accommodate future studies for the entire United States. Additional information is provided in Section 4.4, Update of Precipitation Frequency Data Server.

A detailed outline for NOAA Atlas 14 has been written. It itemizes each theme and estimates the length of each section in the final document. Additional information is provided in Section 4.5, Update of Final Report.

Significant progress was made on the technology review we initiated in the previous reporting period. (See 17th Progress Report for the Semiarid Study, August 2001; Section 5, Issues.) In an L-moment Applications Working Group, a panel of 3 independent experts confirmed our current statistical analysis procedures with suggested modifications.   Finally, discussions held between HDSC and Spatial Climate Analysis Center determined that it is highly likely that Parameter-elevation Regressions on Independent Slopes Model (PRISM) technology can and will be adapted for precipitation frequency studies. Additional information is provided in Section 4.6, Update of Technology Review.

3. Status.

3.1 Project Task List.

The following checklist shows the components of each task and an estimate of the percentage completed per task. Past status reports should also be referenced for additional information.

Semiarid study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [85%]:
- Daily
- Hourly
- N-minute

L-Moment Analysis/Frequency Distribution for 5-minute to 60 days and 2 to 1000 yrs [90%]:

- Daily
- Hourly
- N-minute

Algorithm/Data Plot [85%]

- Establish regions from spatial, topographic and meteorological variables
- Run L-moments for regional growth factors to generate dataset
- Create 2yr-24hr precipitation frequency index map using PRISM
- Create ratio maps - 2yr (1-12) hr/2yr 24hr, 2yr (2-60) day/2yr 24hr
  - Plotting
  - Review hand-drawn analysis
  - Perform digitization
  - Rasterization
- Create regional growth factor maps - (5-100) yr (1-12) hr, (5-100) yr 24hr, (5-100) yr (2-60) day

Precipitation Frequency Maps [50%]

- Create frequency maps for 1-hour to 60-day durations at return periods 2 to 1000 years (seasonal and annual maximum) by multiplying index map rasters and using appropriate regional growth factor and ratio map rasters
- Create maps and/or relations for durations smaller than 1 hour (5, 10, 15, 30 minute) using index map and appropriate conversion factors
- Perform internal consistency checks (comparing rasters of sequential duration and frequency)

Data Trend Analysis [40%]

- Analyze linear trends in annual maximums and variance over time
- Analyze shift in means of annual maximums between two time periods (i.e., test the equality of 2 population distribution means)

Seasonal Analysis [50%]

- Create graphs of percentage of precipitation maximums in each month of a year

Temporal Distributions of Extreme Rainfall [100%]

- Hourly data assembled by quartile of greatest precipitation amount and converted to cumulative rainfall amounts for each region
- Graphs of representative storm-types and seasons

Spatial Relations (Depth-Area-Duration Studies) [30%]

- Analyze critical storms to determine depth-area-duration relations
- Small-area, short-duration relations
- Area-depth curves for areas <500 mi^2 and for >500mi^2
- Families of mass curves and area-depth curves as a function of duration and area size
- A smoothed set of curves to distinguish between convective, tropical and non-tropical storms (if appropriate)

Deliverables [30%]

- Write hard copy of Final Report
    - Maps of analyzed results
    - Graphical relations to obtain intermediate values
    - Seasonal variation
    - Depth-area distribution

- • Temporal distribution of rainfall in extreme storms
- • Implement peer review and interagency review
- Prepare data for web delivery
- Prepare documentation for web delivery
- Publish hard copy of Final Report

3.1.1 Data Collection and Quality Control.

The daily and hourly datasets through December 2000 have been updated. The digitized TD3206 daily dataset from NCDC for the time period before 1948 is currently being added to the dataset. Additional n-minute stations and data from the Riverside County Flood Control District are being evaluated for use in precipitation frequency calculations.

3.1.2 Frequency Distribution Fitting Analyses:

This task evaluates and selects the frequency distribution which provides the best fit for the data. A comprehensive L-moment statistical analysis (Hosking and Wallis 1997) of goodness-of-fit has been done on both daily and hourly data through December 2000 for all durations and all regions to select a best-fit distribution.

3.1.3 Mapping Analyses:

HDSC continues to explore the possibility of using spatial interpolation tools such as the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Discussions with the Spatial Climate Analysis Center have determined that, with the establishment of additional criteria, PRISM technology will be adapted to precipitation frequency data.

3.1.4 Other Analyses:

Annual maximums will be analyzed for statistical trends and shifts using software developed in-house once the dataset update is complete.

A seasonal analysis will be conducted comparing the percentage of precipitation maximums that occur in each month of a year.

Temporal distributions of extreme rainfall in the Semiarid study area have been examined. The results will be presented in graphs representative of different storm-types and seasons. These graphs and accompanying tables are complete.

3.1.5 Documentation and Publication.

The Semiarid study results will be available on the HDSC Precipitation Frequency Data Server once mapping is complete and reviewed. The Precipitation Frequency Data Server displays precipitation frequency values and intensity-duration-frequency curves and tables. The Server is currently password protected and not publicly available. At present, all states can be selected. Where other studies are not yet concluded, information on existing precipitation frequency maps, namely *TP40* (Hershfield 1961) and *NOAA Atlas 2* (Miller et al 1973), is given.

A detailed outline of the Final Report, NOAA Atlas 14, is complete. It includes itemized themes and estimates the length of each section in the Atlas.

4. Progress in this Reporting Period.

4.1 Update of Data Collection and Quality Control.

      The TD3206 daily dataset, which consists primarily of data before 1949, was recently made available by NCDC and is being added to the dataset. These data will be quality controlled using a threshold check and the L-moment discordancy check and included in the precipitation frequency calculations. This update will not change the number of stations in the study area but will increase the length of record at some existing stations.

      Additional stations and data from the Riverside County Flood Control District in California were formatted and quality controlled using the threshold check. There are 40 stations total (32 5-minute stations, 7 15-minute stations and 1 30-minute station). Some of these data are annual maximum values only. Others may contain important events not captured by other datasets. The records of 3 stations (Elsinore, San Jacinto, and Pigeon Pass) are reported to be extensively quality controlled for the past 40 years. These data will be evaluated for use in precipitation frequency calculations and then added to the n-minute dataset in Region 1.

4.2 Update of L-moment Analysis

      L-moment discordancy check and precipitation frequency computations are complete for daily and hourly data through December 2000. N-minute ratios have also been calculated and appear to be consistent with previous results.

4.3 Update of Trend Analysis

      The data will be analyzed for any statistical trends or shifts in annual maximums through time. Software has been developed and revised for this task. The statistical tests include t-tests to deduce any linear trends in annual maxima or in variance. T-tests, Mann-Whitney tests and Chi-squared tests will determine any shifts in means of annual maximums between 2 subsets of data using 1958 as the division. Preliminary work shows that a division of 1958 limits the number of stations for testing because they lack sufficient data. Therefore, 1970 is also being considered as the division to increase the number of stations available for testing. With the refinement of this software, the process of running the Trend Analysis will be simple once the data update is complete.

      As part of this task, the procedure for extracting annual maximums from the dataset was revised. The criteria now ensure that each year has a sufficient number of

monthly maximums, particularly in the rainy season, to accurately extract an annual maximum. A rainy season was assigned to each region in the Study Area based on preliminary seasonal graphs.

4.4 Update of Precipitation Frequency Data Server

The Internet-based Precipitation Frequency Data Server (PFDS) continues to be developed, tested and enhanced. Most importantly, the areal calculation functionality has been modified to be more flexible and accurate. Unlike previous beta versions, the PFDS now uses a list of user-entered longitude/latitude points to calculate the area size and areal precipitation frequency estimates. Originally it was feared that the areal-calculations would require an unacceptable amount of time to compute, but with the new modifications, the calculation time is very fast.

Another important PFDS modification has been the initial development of a new web page framework. The new framework will better accommodate such items as Help, General Information, Feedback, Files for Downloading, Background Information, and Contact Information. The new framework includes a PFDS Users Guide as well as an on-line NOAA Atlas 14 Mini-Manual.

4.5 Update of Final Report

A detailed outline for NOAA Atlas 14 has been written. It itemizes each theme and estimates the length of each section in the final document. The format of NOAA Atlas 14 will be similar to NOAA Atlas 2 but also include explicit references regarding the L-moment procedure for estimating precipitation frequency.

4.6 Update of Technology Review

We have made significant progress on the technology review we initiated in the previous reporting period. (See 17th Progress Report for the Semiarid Study, August 2001; Section 5, Issues.)

4.6.1 Data Collection and Quality Control

HDSC has defined a well-developed and efficient set of procedures for data collection and quality control. The procedures have been refined over time for extracting and quality controlling data from the National Climatic Data Center. The procedures and data formats are structured to fit efficiently into sequential processes for producing updated rainfall frequency estimates. We plan to continue using these procedures. HDSC plans to publish the final quality-controlled time series used in its analysis.

4.6.2 Statistical Analysis

Based on recommendations during the previous quarter by independent experts, in this quarter we held detailed face to face discussions with David Goldman (U.S. Army Corps of Engineers), Ned Guttman (NOAA, National Climatic Data Center), and John Hosking (IBM). The discussions confirmed our general plan to use the statistical procedures described in *Regional Frequency Analysis: An Approach Based on L-Moments*, Hosking and Wallis, 1997. In their book, Hosking and Wallis discuss possible variations in specific procedures. HDSC will document and publish those areas where we have made a choice between possible alternatives. We have also decided to adopt the procedures described by Hosking and Wallis for assessing the accuracy of estimated values.

HDSC will use the *unbiased plotting-position estimators* unless we can demonstrate that careful use of the *biased plotting-position estimators* is more effective. During the next quarter we will proceed with the use of the unbiased estimators while conducting an assessment of the biased estimators. We do not expect this assessment to impact our schedule.

4.6.3 Spatial Interpolation

HDSC held discussions in Corvallis with Oregon State University's Spatial Climate Analysis Service. In the previous reporting period we mentioned our concerns about legal issues relating to the use of their PRISM technology. Discussions suggest that these legal issues can be overcome. While PRISM has been accepted for spatial interpolation of other climatic parameters, it has not been proven in the analysis of rainfall intensity frequency duration estimates. Technical discussions and more detailed demonstrations of PRISM capabilities have convinced us that it is highly likely we will be able to use PRISM for spatial interpolation of the point estimates derived from regional analysis using L-moments. As a result, HDSC has entered into detailed

discussions with the Spatial Climate Analysis Service to first conduct a final proof test of PRISM technology and then use the technology in our production process.

5. Issues.

5.1 Personnel

Dr. Lesley Julian has announced her retirement effective September 30 2001. Dr. Julian was a full time Federal Government employee and we have begun the process of seeking a replacement. Mr. Geoffrey Bonnin is now directly managing the HDSC.

6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on in the next quarter are also included in this section.

Data Collection and Quality Control [October 2001]
L-Moment Analysis/Frequency Distribution [October 2001]
Algorithm/Data Plot [December 2001]
Precipitation Frequency Maps [December 2001]
Temporal Distributions of Extreme Rainfall [complete]
Trend Analysis [October 2001]
Seasonal Analysis [November 2001]
Spatial Relations (Depth-Area-Duration Studies) [January 2002]
Implement Precipitation Frequency Data Server [January 2002]
Implement review by peers [January 2002]
Write hard copy of Final Report [January 2002]
Publish hard copy of Final Report [March 2002]

6.1 Data Collection and Quality Control.

Quality control is an iterative process that continues throughout the process. Threshold checks and discordancy checks are complete for all data except the pre-1948 data and Riverside data.

Semiarid Precipitation Frequency Study
Update of *Technical Paper No. 40, Technical Paper No. 49* and *NOAA Atlas 2*
Eighteenth Progress Report, October 2001

6.2 L-Moment Analysis/Frequency Distribution.

A comprehensive L-moment statistical analysis will be done on all daily, hourly and n-minute data to provide the best quantile estimates. The tasks involved with the statistical analysis will take roughly one month for all 24 regions in the Semiarid study area.

6.3 Trend Analysis and Seasonal Analysis

The completed dataset will be analyzed for any trends or shifts in annual maximums through time. This task will involve running existing statistical software and analyzing results. A seasonal analysis will be conducted comparing the percentage of precipitation maximums that occur in each month of a year. The end products of these tasks are analyses and graphs that will be included in the final document.

6.4 Precipitation Frequency Maps.

A sophisticated cartographic-map making process has been designed using the latest release of ArcView software. During the next few months the review and revision process will result in a final cartographic-quality map template. This map template will then serve as the basis for all future precipitation frequency maps. The maps will be available both online (as ArcInfo ASCII raster, ArcView GIS shapefile, postscript and JPEG files) and in a hardcopy form with the final reports.

6.5 Precipitation Frequency Data Server.

Once the data and mapping are complete, the precipitation frequency estimates for the Semiarid study will be available from the HDSC web-based Precipitation Frequency Data Server. The Precipitation Frequency Data Server will display precipitation frequency values, as well as intensity-duration-frequency (IDF) curves and tables. Eventually, all states will be selectable from the opening U.S. map.

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